Thermal demagnetization constraints on the rate of emplacement of the Pine Valley Mountain Laccolith, Utah

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Abstract

Pine Valley Mountain in the southwestern corner of Utah is the site of a laccolith, the cooled remnants of an inflating magma chamber in between two layers of pre-existing rock. Magma chamber inflation can cause a dome like uplift in the overlying rock units leading to oversteepening of the slope, triggering landslides and volcanic eruptions, like the Mt. St. Helens eruption in 1980. Through paleomagnetic analysis we can determine the timescale over which the emplacement occurred by observing how much wander the Earth's magnetic pole experienced as the sheets of magma were emplaced and cooled. If results show a small amount of wander in the Earth's magnetic pole, that will indicate a very rapid (in the context of geologic time) emplacement which could result in a catastrophic landslide-triggered volcanic eruption. If the magnetic pole experiences a large amount of wander, that suggests a slower rate of emplacement and contradict a landslide-triggered eruption event.

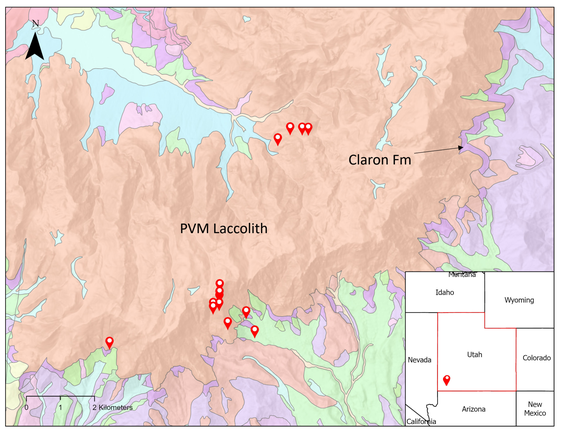

Figure 1. Geological map of the Pine Valley Mountain laccolith located in SW Utah. The inset map shows the general location of the study area. Red points indicate sampling locations. Important geologic formations are labeled on the map.

Introduction

Pine Valley Mountain (PVM) laccolith is a 20 Ma pluton composed of Miocene intrusive igneous rock. Landslides on the flanks of the laccolith could be associated with rapid inflation causing an eruption similar to Mt St Helens. Since PVM emplacement occurred millions of years ago it has since been exposed at the surface due to uplift and erosion. Unlike Mt St Helens, it is difficult to precisely determine the time scale over which the PVM laccolith was emplaced. The magnetic signal preserved by the cooling magma of this laccolith at the time of emplacement, records the position of the magnetic pole. Using that magnetic record, we can track the wander of the Earth's magnetic pole to determine if how rapidly it was emplaced.

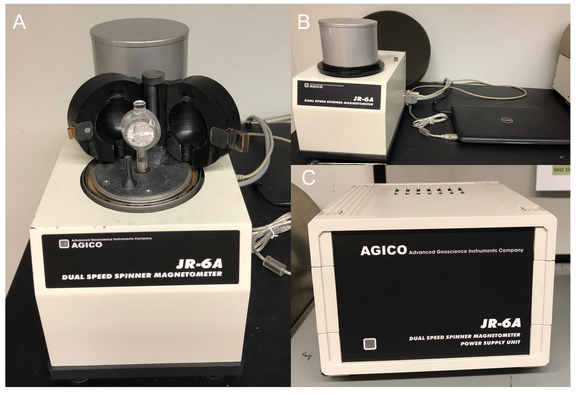

Figure 2. The AGICO JR-6A Spinner Magnetometer is composed of two pieces of equipment (A and C) that are connected to a laptop computer. The rock core sample is aligned and secured in a holder and then placed in the machine to measure the magnetization.

Methods

- Eighteen cores were treated using a thermal remanent demagnetization technique and measured using a JR-6A Spinner Magnetometer from 0°C to 700°C (Fig. 2).
- The TSD-I Thermal Specimen Demagnetizer was used to heat the samples up in 13 steps and erase the magnetization (Fig. 3).
- A vector component analysis was performed using Python 3 script adapted from Tauxe et al. (2016) to track the demagnetization of each core.
- The data were then plotted on a stereonet to determine the amount of polar wander the samples recorded. A cumulative secular variation graph was also created to illustrate the different rates of emplacement that occurred through out the pluton.

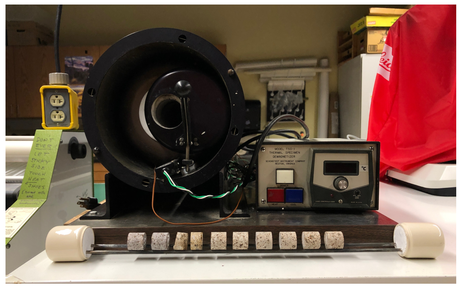

Figure 3. The TSD-I Thermal Specimen Demagnetizer was used to heat samples up incrementally to erase the magnetization in the rock cores. The boat pictured at the bottom held the cores throughout the heating and cooling of the experiment.

Results

- Nine of the eighteen samples fully demagnetized, had a consistent thermal remanent magnetization and a positive inclination (Fig. 4).
- Most of the samples displayed a NW trend with a steep plunge when plotted on a stereonet (Fig. 5). The data are consistent with the 20 Ma pole position of Torsvik et al. (2012).
- A cumulative secular variation graph suggests emplacement of the bottom 2/3 of the pluton over 7609.2 +/- 1285.5 years (Fig. 6).

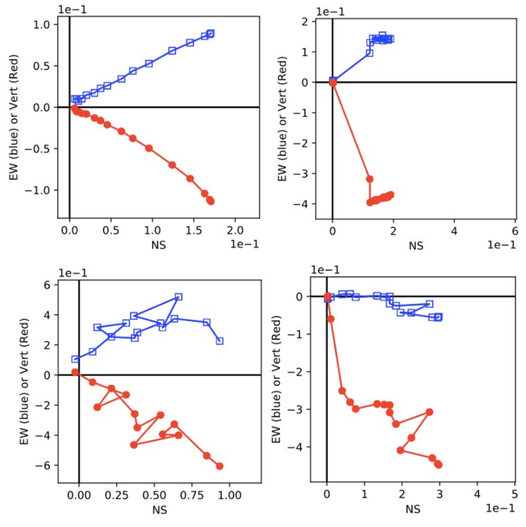

Figure 4. Vector component diagrams showing results from thermal demagnetization experiments. Samples that fully demagnetized, were displayed in four different ways; a) one-component system straight to the origin, b) two-component system to origin, c) two-component system with randomness to the signal, or d) a two-component system with a systematic wander (plots created using the software package of Tauxe et al., 2016).

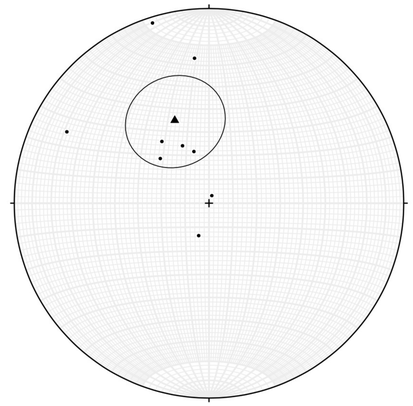

Figure 5. A stereonet plot with the nine remaining sites. The triangle and uncertainty ellipse were calculated using the Fisher mean. The sites display a statistically significant difference, suggesting the rapid emplacement hypothesis is incorrect.

Discussion

Nine of the 18 samples fully demagnetized, the signal decayed to the origin, and the magnetic orientation was consistent with the expected direction. While the thermal demagnetization technique was successful, the instantaneous emplacement of the Pine Valley Mountain Laccolith must be rejected due to a statistically significant difference in the mean uncertainty of the sample sites. The sites are too dispersed to suggest emplacement on anything shorter than a timescale of a couple thousand years. The secular variation graph shows most of the magma being emplaced initially over thousands of years.

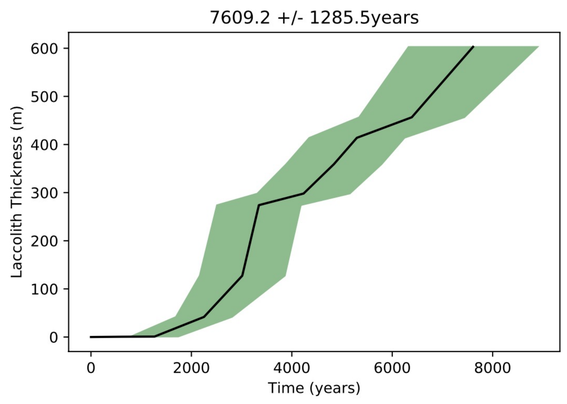

Figure 6. A cumulative secular variation graph. The time is plotted against the laccolith thickness to illustrate variation in emplacement over time. The thickness implies the oldest rocks at the bottom and youngest at the top

Conclusion

The thermal demagnetization technique proved successful for 9 out of 18 samples from the Pine Valley Mountain. The hypothesis that emplacement of the Pine Valley Mountain laccolith was geologically instantaneous (<1 year to a decade) can be rejected due to the statistically significant difference between the orientation of the thermoremanent magnetization in different samples. Our analysis suggests emplacement occurred on a time scale of approximately 7500 years.

References

Hacker, D.D., Holm, D.K., Rowely, P.D., and Blank, H.R., 2002 Associated Miocene laccoliths, gravity slides, and volcanic rocks, Pine Valley Mountains and Iron Axis region, southwestern Utah: Geological Society of America Field Trip Guides, Rocky Mountain Section, p. 49.

Tauxe, L., R. Shaar, L. Jonestrask, N. L. Swanson-Hysell, R. Minnett, A. A. P. Koppers, C. G. Constable, N. Jarboe, K. Gaastra, and L. Fairchild (2016), PmagPy: Software package for paleomagnetic data analysis and a bridge to the Magnetics Information Consortium (MagIC) Database, Geochem. Geophys. Geosyst., 17, doi:10.1002/2016GC006307.

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